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# ENGINE STARTER SYSTEM HAVING DUTY-CONTROLLED SWITCHING DEVICE

## CROSS REFERENCE TO RELATED APPLICATION

This application is based on and incorporates herein by reference  
5 Japanese Patent Application No. 2001-103119 filed on April 2, 2001.

## BACKGROUND OF THE INVENTION

The present invention relates to an engine starter system for  
starting an engine.

10 In a conventional engine starter system, when an engine key  
switch is turned on, a solenoid switch generates magnetic power with  
its exciting winding being energized. When a plunger, moved by the  
magnetic power, closes contact points for a motor of the starter,  
a hitting sound is generated. In order to reduce the hitting sound,  
15 a large current (rush current) is required to be restricted when  
the key switch is turned on. Therefore, a current restricting device  
is connected to the exciting winding in series, thereby restricting  
a current flowing into the exciting winding by the current restricting  
device.

20 However, the output of the starter is reduced due to a voltage  
drop at the current restricting device. Further, when the capacity  
of a battery is reduced and the voltage of the battery is reduced  
by energizing the motor, the operation of starting the engine cannot  
be sometimes maintained due to the voltage drop at the current  
restricting device. Furthermore, a low-cost current restricting  
25 device is desired to be used in the engine starter system for reducing  
the production cost of the engine starter system.

## SUMMARY OF THE INVENTION

The present invention therefore has an object to provide an improved engine starter system.

Further, the present invention has an object to provide an engine starter system, which can surely start an engine even when the capacity of a battery is reduced.

According to the present invention, an engine starter system includes a first energizing circuit having a current switching device, a second energizing circuit having a relay, and an electronic control circuit for controlling the operations of the current switching device and the relay. The current switching device and a motor armature are connected in series, and the relay contact points and the armature are connected in series. The first energizing circuit energizes the armature by turning on the current switching device, and the second energizing circuit energizes the armature by closing the relay contact points.

Accordingly, the armature can be energized by suitably changing any one of the first and second energizing circuits. For example, when an engine is started, the armature is energized by turning on and off the current switching device with a varying duty ratio, so that the current flowing through the armature is controlled to increase gradually for reducing a rush current. When a large current is required, the armature is energized by closing the relay contact points thereby shorting the switching device.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and advantages of the present invention will be more readily apparent from the following detailed description of preferred embodiments when taken together with the accompanying

drawings, in which:

FIG. 1 is a circuit diagram of an engine starter system according to the first embodiment of the present invention;

FIG. 2 is a circuit diagram of an engine starter system according to the second embodiment of the present invention; and

FIG. 3 is a circuit diagram of an engine starter system according to the third embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described hereinafter with reference to various embodiments.

##### (First Embodiment)

As shown in FIG. 1, an engine starter system 1 has a solenoid switch 2 mounted on a starter (not shown), which has a pinion 3 and an armature 11. This solenoid switch 2 pushes the pinion 3 to be engaged with a ring gear 20 of an engine (not shown) by its driving force. As rotation force of a starter motor is transmitted from the pinion 3 to the ring gear 20, the engine is started. The starter system 1 includes a duty-controlled current switching device 4 for controlling the current flowing through the armature<sup>11</sup>, a shorting relay 5 connected in parallel with the current switching device 4 for electrically shorting the current switching device 4, and an electronic control circuit 6.

The solenoid switch 2 includes an exciting winding 8, a plunger 9, inside contact points 10 and the like. The exciting winding 8, energized when a key switch 7 is turned on to a starting position ST, generates magnetic power, so that the plunger 9 is moved by the magnetic force to engage the pinion 3 with the ring gear 20. According

to the movement of the plunger 9, the inside contact points 10 are opened and closed. The starter motor is a D.C. motor where the armature 11, when energized, generates rotation force.

The current switching device 4, connected in the wiring between a battery 12 and one of the inside contact points 10, is controlled in a pulse width modulation (PWM) by the electronic control circuit 6. That is, the current switching device 4 is turned on and off repeatedly with a varying duty ratio to vary the current supplied to the armature 11. The relay 5 is composed of relay contact points 5a and an exciting winding 5b for opening and closing the relay contact points 5a. The relay contact points 5a and the current switching device 4 are connected in parallel. The electronic control circuit 6 is operated by the battery 12 when the key switch 7 is turned on to a power-on position ON. The electronic control circuit 6 controls the operation of the current switching device 4 and the relay (exciting winding 5b) based on engine condition signal, a current flowing through the armature 11 (armature current), a starting mode signal and the like. The engine condition signal is a rotation speed of the engine, for example.

The starting mode signal is a normal starting mode signal for performing a normal starting mode and an economy-running starting signal for performing an economy-running starting mode, for example.

In the normal starting mode, the engine is started by turning on the key switch 7 to the starting position ST. In the economy-running starting mode, the engine is automatically started without turning the key switch 7 to the starting position ST, when a predetermined condition (e.g., starting to depress an accelerator pedal after

releasing a brake pedal) is satisfied. This economy-running starting mode is initiated when a vehicle starts to run after an engine stop at a traffic light.

Next, description will be made on operation of the engine starter system 1. In the normal starting mode, when the key switch 7 is turned on to the starting position ST, the exciting winding 8 is energized to move the plunger 9 so that the pinion 3 is engaged with the ring gear 20 and the contact points 10 are closed. The electronic control circuit 6 controls the current switching device 4 in a PWM and gradually increases the armature current by gradually increasing the duty ratio. Thereafter, when the armature current becomes larger than an allowable current value because the engine requires a larger starter torque under the low temperature condition, the electronic control circuit 6 energizes the exciting winding 5b, so that the relay contact points 5a are closed to short the current switching device 4. Thus, the armature current is supplied continuously from the battery 12 through the relay contact points 5a, and the armature 11 is energized without being interrupted by the current switching device 4.

When the engine is completely driven and energizing the armature 11 is stopped by turning off the key switch 7 from the starting position ST, the inside contact points 10 are opened by opening the relay contact points 5a by stopping energizing the exciting winding 5b. When the inside contact points 10 of the solenoid switch 2 melt and do not open the circuit for some reason, the relay contact points 5a are opened and the current switching device 4 is held turned off, thereby preventing the exciting winding 8 of the solenoid switch

2 from being overheated.

In the economy-running starting mode where the engine can be started using a current lower than the allowable current value of the current switching device 4 because the engine is warm and requires less starter torque, the armature current is controlled through the current switching device 4 until the engine is completely started. In this case, the armature current is controlled so as to follow the fluctuation of cranking torque of the engine.

As described above, the engine starter system 1 includes a first energizing circuit for energizing the armature 11 by turning on and off the current switching device 4 with the gradually increasing duty ratio and a second energizing circuit for energizing the armature 11 by closing the relay contact points 5a. Therefore, for example, when the engine is started, the current switching device 4 is turned on, and the armature current is gradually increased using the current switching device 4. In this case, a large current (rush current) can be prevented from flowing through the armature 11 at the time of starting to energize the armature 11, thereby restricting useless electric power consumption.

When the armature current becomes larger than the allowable current value of the current switching device 4, the current switching device 4 can be electrically shorted by closing the relay contact points 5a, so that the armature current flows through the relay contact points 5a. As a result, a low-current switching device can be used for the current switching device 4. In this case, a voltage drop at the current switching device 4 can be eliminated, thereby restricting the output of the engine starter system 1 from being

reduced.

At the time of stopping energizing the armature 11, the solenoid switch 2 is turned off after opening the relay contact points 5a. Therefore, when the inside contact points 10 of the solenoid switch 2 are opened, an arc current can be prevented from being generated at the inside contact points 10, thereby lengthening the lifetime of the inside contact points 10.

In the economy-running starting mode, the armature 11 can be energized by controlling only the current switching device 4 while the relay contact points 5a are opened, thereby reducing the frequency of using the relay contact points 5a and improving the durability of the relay contact points 5a. In the economy-running starting mode, the current switching device 4 is controlled so that the armature current follows the fluctuation of cranking torque of the engine, so that the rotation speed of the armature 11 can be controlled in accordance with the rotation speed of the engine. Therefore, the starting sound at the time of cranking the engine can be reduced.

(Second Embodiment)

As shown in FIG.2, in the engine starter system 1 according to the second embodiment, the current switching device 4 and the relay contact points 5a are connected in the wiring between the armature 11 and the ground terminal at the lower voltage side of the armature 11. The control method for the current switching device 4 and the relay 5 (exciting winding 5b) is identical to that in the first embodiment, thereby obtaining the same operational effect as in the first embodiment. Since the current switching device 4 is connected in the wiring at the lower voltage side of the armature



11, the current switching device 4 can withstand a high voltage.

(Third Embodiment)

As shown in FIG. 3, in the engine starter system 1 according to the third embodiment, the solenoid switch 2 has no inside contact points (10 in FIG. 1). The armature 11 is directly connected to the first energizing circuit and the second energizing circuit, the solenoid switch 2 is used only for pushing out the pinion 3 for engagement with the ring gear 20. In this case, for example, in the economy-running starting mode, the pinion 3 can be maintained to be engaged with the ring gear 20 while the solenoid switch 2 is maintained energized. Therefore, the engine can be started in a short time.

(Other embodiments)

In the above embodiments, the electronic control circuit 6 may be constructed to determine the time of closing the relay contact points 5a based on any one of the time passing after the current switching device 4 is turned on, the armature current, the rotation speed of the engine and the rotation speed of the armature 11. In this case, too, when the current flowing through the current switching device 4 becomes larger than the allowable current value, the relay contact points 5a may be closed.

Further, when predetermined time passes after the electronic control circuit 6 turns on the current switching device 4, the electronic control circuit 6 may turn off the current switching device 4 and open the relay contact points 5a. In this case, for example, even when the solenoid switch 2 is electrically shorted, the energization of the armature 11 can be stopped by turning off the

current switching device 4 and opening the relay contact points 5a.

While the present invention has been shown and described with reference to the foregoing preferred embodiments, it will be apparent to those skilled in the art that changes in form and detail may be made therein without departing from the scope of the invention.

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